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FACTS ABOUT FOREST INSECT AERIAL SPRAYING WITH DDT TO CONTROL SPRUCE BUDWORM

A Digest of Available Literature

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INTRODUCTION

The spruce budworm infestation in Montana in 1955 covered 2,903,000 acres. It has spread to this acreage since 1948. The average annual rate of increase is 414,714 acres for each of the years 1949 through 1955.

Since inception of the outbreak in central Montana in 1948, only two small areas of infestation have subsided from natural causes. Approximately 15 billion board feet of Douglas-fir sawtimber and 5 billion board feet of spruce sawtimber in Montana are in jeopardy from the spruce budworm, along with several million acres of younger stands of Douglas-fir, alpine fir, and spruce.

Control of spruce budworm outbreaks by airplane spraying has been successful in large scale operations conducted in Oregon and Washington. One pound of DDT in 1 gallon of fuel oil is applied per acre during a short period in early summer, when expanding (fir) buds expose the worm larvae. Such spray operations are 90% or more effective in reducing infestation. The acceptable mortality rate on spray jobs is 90%.

The several species of insect parasites, which are natural enemies of the spruce budworm, attack at different stages of development in the life cycle of the spruce budworm. This favors survival of parasites on spray areas because only those insect parasites that are exposed, or on the wing at the time of spraying are killed. Investigations by the former Bureau of Entomology and Plant Quarantine in Oregon determined that survival of insect parasites on sprayed areas was excellent. The Biology Division of the Department of Agriculture of Canada report that they have no evidence that parasitism has been adversely affected in sprayed areas.

The objective of forest insect control work is to save valuable timber resources with a minimum of damage to other forest resources to the utmost practicable degree. The decision to spray must always be weighed carefully to make sure that results justify any possible harmful effect on other forest resources. In the case of the spruce budworm the economic loss of timber would not be the only loss. Large areas of dead and dying trees greatly increase the fire hazard. Fires jeopardize live timber and fire-damaged watersheds decrease wildlife, fish, watershed, and aesthetic values.

The Fisheries Research Board of Canada reports that one of the major detrimental factors to salmon management is deforestation. The virtual disappearance of a population of early running Chinook salmon, which formerly entered the Cowichan River, a West Coast stream, in the spring and remained in the watershed until early autumn, is ascribed to increased summer temperatures of the water caused in part by deforestation following logging and fire.

In the job of spraying forest insect pests foresters and entomologists are concerned about the effect DDT may have on forest wildlife and fish. Control of many forest insects with DDT can be obtained with very low dosages which minimizes serious permanent injury to beneficial insects and other animal life. Experiments and actual spray jobs have provided much valuable information.

Nearly all organic and mineral poisons are specific to a degree. They do not affect all plant and animal species equally. If they did, the advantage of control of undesirable species would be more than offset by the loss of desirable and beneficial forms. DDT is no exception to this rule. Certainly such an effective poison for the spruce budworm will destroy some beneficial insects, fish, birds, and small animals. Forest entomologists and other research workers have spent much time in developing a mixture and dosage per acre that will kill spruce budworms and do the least harm to other biological species. In nearly all of the many cases studied, they found that 1 pound of DDT mixed in 1 gallon of fuel oil and spread by an airplane as a fine mist spray over one acre of land at the proper time was 90-100% effective in killing spruce budworms, but caused only slight loss of desirable forest life under average or ordinary circumstances. The amount of DDT that actually reaches the ground and water surfaces varies considerably, depending upon weather, type of spray apparatus, differences in tree crown density, topography, and many other factors.

One of the most important factors in minimizing damage to other resources is effecting a control program while the area of infestation is small. Control programs covering millions of acres multiply harmful effects in the same proportion.

An effective control program for spruce budworm in this region requires the cooperation of all State and Federal agencies, and private landowners as well as an informed citizenry. This report is a digest of literature and reports covering projects and experimental work on effects of DDT spraying.

TOXICITY OF DDT

Effects as determined by laboratory analysis or toxicological information should not be used alone to determine chemical hazards to man or animals. Generalizations are better avoided. Factors operating in one area may not operate in another; or chemicals may be used at the same locality in different seasons or years without necessarily producing the same results.

"Acute" usually indicates the effects of whatever degree from a single exposure to a toxic poison. "Chronic" implies multiple dosage over an extended period of time. In spraying the spruce budworm we are concerned only with the acute or single dosage since the area is usually sprayed only once. In determining effect upon forest areas we are not only concerned with direct chemical toxicity, but also with the effects upon food and cover of any species involved. Factors of environment affect toxicity. This gives variable results in what appears to be similar circumstances. The

degree of poisonousness of toxicity also varies with the type of formulation or mixture. The lethal (killing) dose of DDT for the same species may be different for an emulsion, solution, or suspension, or type of insecticide mixture.

MAN

Man is considered as one of the more susceptible species but DDT is also one of the safest insecticides available for human use. This is true because the toxicity hazard by inhalation or skin absorption is very low in relation to the amounts of DDT contained in insecticide mixtures normally used. Nevertheless, skin poisoning is possible. A few human deaths have occurred, mostly from accidental swallowing or ingestion of the insecticide usually dissolved in an oil base. A recent study by the U. S. Public Health Service indicates that amounts of DDT eaten by the average person through the residue left on fruits and vegetables from spray is not harmful even though it is stored in the body fat. It was found that after the body stores a maximum amount no more is stored in spite of continued intake.

The hazard to man from the spraying of DDT on forest areas at the rate of one pound per acre is almost negligible. Studies by the former Bureau of Entomology and Plant Quarantine indicate that damage to stream fauna is due to the amount of DDT deposited by the initial spraying and not from DDT washed or leached into the stream at a later date. Therefore, if the initial spraying was of insufficient dosage to affect humans through drinking water, subsequent amounts leached or washed into the stream would not appear to be dangerous.

LIVESTOCK

DDT is a relatively safe insecticide for livestock. All livestock can tolerate single applications of 8% DDT. As many as 10 applications of 2% DDT at 2 week intervals have failed to produce ill effects. Acute poisoning of livestock is unlikely to occur, but chronic poisoning is possible. Steers fed on silage from a crop containing 3 lbs. per acre of DDT grew normally. Goats and sheep remained entirely normal on pasture treated at 7.5 lbs. per acre.

DDT is secreted in milk of mammals after having accumulated in the butterfat formed in the body. The danger from DDT residue on hay and ensilage subsequently fed dairy cattle is that the insecticide is transferred to the milk. The use of DDT is therefore prohibited on crops to be used for winter feed of dairy cattle and the sale of milk which contains demonstrable amounts of DDT has been banned in the United States.

It is safe to use DDT for dogs but it should be used sparingly on cats as they may be poisoned by relatively small amounts. Chickens should not be sprayed or dipped with DDT.

SOIL AND VEGETATION

Experiments conducted by the Department of Agriculture have shown that DDT is an unusually stable organic compound when in the soil. Large amounts added to certain soils decompose at the rate of about 5% per year. There is no cause for concern about harmful accumulation in the soil when only 1 to 5 pounds per acre are used in some years. There is danger where heavy applications are made every year on the same tracts of land planted to orchards, truck, or other special crops. Grasses and other crops are tolerant, but some legumes and other plants are sensitive and heavy repeated dosages may develop enough residue to harm these sensitive crops.

FISH

The U. S. Fish and Wildlife Service has conducted extensive experiments in the eastern United States. These experiments are not necessarily applicable to western conditions, but they may be indicative of what might be expected. In Pennsylvania, a small stream was sprayed by airplane with an oil solution of DDT applied at the rate of one pound per acre with the plane following the course of the stream. Most of the mortality occurred within two days after spraying. Warm water fish were affected most. Sampling of the native brook trout population before and after spraying indicated that 1.3% of the trout population was killed.

Studies by the Fish and Wildlife Service in Idaho and Wyoming on actual spray jobs covering more than 50 streams resulted in some good information. In Idaho, with an application of one pound per acre of oil solution of DDT, mountain suckers and bullheads were killed, but speckled dace, redside shiners, and three species of trout were not adversely affected. In Wyoming several cutthroat trout were killed by DDT applied at the rate of 2-$\frac{1}{2}$ pounds per acre. These represented only a small percentage of the population.

The effectiveness of DDT is dissipated rapidly in running water. Other variables affecting toxicity are water temperature, amount of oxygen, PH values, water clarity, and mineral content.

The Fisheries Research Board of Canada reported severe losses of young salmon in the Miramichi River from an aerial spray job using 1/2 pound of DDT in an oil mixture. According to the report, young salmon were held in cages in the streams during spray operations. About 80% of those held within the sprayed area died within a week. Ten miles below the area of direct application only 16% died, and 15 miles below only 4% died within four weeks. No such mortality had ever been observed in earlier years. There was no indication that fish loss was due to starvation. Fish food organisms were definitely affected, but the loss in no way seemed to be connected with the loss of young salmon.

On the Teton National Forest in Wyoming an area was sprayed for control of the mountain pine beetle which included 3/8 of a mile of stream with a flow of 0.7 cubic feet per second. The treatment was 5 pounds of DDT in 2

equal sprayings. The stream area supported a large population of cut-throat trout. After the spraying only 11 dead trout were found. Loss was lighter than expected for such a high dosage. Characteristics of the stream appeared to be responsible in two ways. First, the occurrence of several beaver dams retarded the water flow and minimized mixing of the spray by flow turbulence. Second, spray that did mix with the water may have had its toxicity neutralized by the mud in the water and on the bottoms of the beaver ponds. Laboratory work has shown that muddy water reduces the toxic effectiveness of DDT and minimizes fish losses.

E. R. Kalmback and J. P. Linduska of the Fish and Wildlife Service report that in most cases where one pound of DDT per acre has been used in aerial sprays only about ¼ of that amount has been deposited on water surfaces. This has been sufficient to cause some fish mortality but not enough to be significant in terms of total population. Young fish have shown a higher susceptibility than older fish of the same species, with forage species being more seriously affected than game species.

In an article "Some Considerations of the Biological Effects of DDT," C. H. Hoffman and J. P. Linduska report that as a result of extensive experimentation one-pound dosage per acre represents the approximate limit under which forest insect control work can be done without appreciable losses in aquatic environments.

The Fish and Wildlife Service carried on extensive experiments to determine the effect of feeding DDT sprayed insects to fresh-water fish. Insects sprayed with a DDT suspension or an oil solution at a rate equivalent to one pound of DDT per acre, fed to fingerling bluegills, smallmouth bass, and largemouth bass gave erratic results. Some fish apparently were killed by devouring relatively small numbers of sprayed insects and others gorged without effect. Death attributable to DDT occurred after variable periods.

Fish eating the insects sprayed with DDT in oil were usually more easily killed and died earlier than those eating insects sprayed with a DDT suspension in water. Large fish appeared less sensitive than small fish to DDT sprayed insects.

Fish recently removed from nursery ponds where they were well fed survived the effects of DDT better than those kept in holding ponds without natural or artificial food. Well-fed fish that gorged upon insects sprayed with DDT survived in large numbers even though they were fasted after the test feeding. Laboratory and outdoor experiments indicate that the condition of fish is a very important factor in their susceptibility to DDT.

In 1953 the State Game & Fish Commission of Oregon was planting sea-run steelhead in Meadow Creek at the time of spraying and extensive killing of these fingerling fish occurred almost immediately. The loss was confined to a five mile section of the stream used as a spray block boundary. A B-18 made several trips over the stream and it received a heavy dosage of DDT.

Meadow Creek was very low at the time with a very slow flow rate and the young steelheads concentrated in large numbers in the shallow pools. It is believed that the heavy loss of fish could have been avoided if the contractor had followed spraying instructions to spray boundaries only once.

The report from Oregon indicates that trout fishing was unusally poor for several weeks following spraying because the fish were full of insects that had been killed by the DDT. Fishing became normal again when the excess food supply was consumed or carried away.

During the 7 year spray program in Oregon many fine trout streams were sprayed and also many lakes. Portions of the upper McKenzie and Willamette Rivers were sprayed with no serious loss of fish being reported. As far as is known the only substantial loss occurred in Meadow Creek.

Study of fish losses on the Yellowstone River following the 1955 spray program is being continued, and it is hoped that sufficient factual information will be obtained to determine effect of DDT and the rate of recovery.

Crayfish are very susceptible to DDT, and it can be expected that under certain circumstances numbers of crayfish will be lost even with dosages of one pound per acre. In Clatsop County, Oregon, spraying for the control of hemlock looper was begun in early June and continued for several weeks, mostly with less than one pound of DDT per acre. A large percentage of the crayfish in the Necowcum River, which crosses the tract, were killed, but those in a nearby unsprayed stream remained healthy. Fish were apparently unaffected.

AMPHIBIANS

On the Patuxent Research Refuge the Fish and Wildlife Service put out open-topped cages stocked with adults of green pickerel and bull frogs, with adult toads, and with frog and toad tadpoles. The area was sprayed by plane at the rate of one pound of DDT per acre. None of the animals were affected.

A second study was made in a series of artificial ponds in which adults and tadpoles of several species of toads and frogs were living. In the deeper ponds treated with one pound of DDT per acre, no dead or sick animals were found, but in the shallow pond (5 inches deep in the center) several frogs and frog tadpoles and a young water snake were killed.

AQUATIC INSECTS

In making appraisals of fish food losses due to DDT spraying work or experiments, it seems important to consider a few statements from Paul K. Needham's book, "Trout Streams."

"In order to obtain fair averages of food conditions at any point in a stream it is necessary to secure a comparatively large number of samples because of the great variability from place to place."

"It will be noted that high average number of organisms per square meter does not necessarily indicate high poundage of food per acre."

"There are peaks of seasonal abundance."

"Peak production seems to be in the spring."

The former Bureau of Entomology and Plant Quarantine has measured in some detail by field tests the effect of DDT on aquatic insects which furnish fish food. In most cases a one-pound per acre application caused a marked reduction in numbers of bottom and surface species. However, recovery was rapid. Within a year the quantity of organisms was about the same as before, although some change in species composition was evident. There has been no indication that the temporary shortage of these aquatic insects appreciably impaired the productivity of the water.

Various species of aquatic insects showed great differences in susceptibility to DDT. Insects living on the surface of the water or coming to the surface to breathe were extremely susceptible to an oil solution of DDT, and those living in the bottoms of ponds and streams were relatively immune. For this reason nymphs of dragon flies in streams are seldom affected. In swift streams there are many species that obtain all or much of their food by straining it from water. This accounts for the susceptibility of Caddice flies, Mayflies, and black flies.

The experiments indicate that when a stream and its watershed are sprayed by airplane nearly all damage to the fauna in the stream is by DDT deposited on its surface, not by DDT washed or leached into the stream later. The rate of repopulation of a pond or stream depends upon how soon the DDT disappears from the water and the length of life cycle, number of survivors, and possibilities for migration of the species involved. In a pond the DDT may remain in lethal amounts for days or weeks, depending upon dosage, drainage, and other factors. In a stream most of it may be carried off in a day. Many pond species have several generations a season, and it is believed that as a group they have a greater tendency to migrate than do stream species. Hence, a small pond regains most of its fauna by immigration in a few weeks after DDT is no longer effective. Most stream species take a year for a generation, and many of the larger so-called predator species take several years.

Stream insects providing fish food in many of the experiments and spray jobs were drastically reduced, but this reduction has not seemed to have any noticeable effect on fish population.

C. H. Hoffman and E. P. Merkel conclude that airplane application of DDT at the rate of one pound per acre, which affords good control of many forest pests, causes no permanent damage to stream-inhabiting animal populations.

BIRDS

The Fish and Wildlife Service has conducted experiments to determine the effect of aerial spraying of DDT on birds. During the first week after the spraying operations (with one pound of DDT per acre) the bird population dropped approximately 12 percent on the sprayed area, 5 percent on the control area and 10 percent on the area, adjacent to the sprayed tract, presumably to completion of nesting or loss by predation. These figures are too nearly alike to indicate effects of DDT. No marked difference in the population occurred during several weeks after spraying, and there was no apparent movement away from the sprayed area.

At the time of spraying eggs or young were under observation, twenty-three in the sprayed area and twelve in the control. No difference in the hatching or survival was observed on either sprayed or unsprayed areas.

Bureau of Entomology and Plant Quarantine experiments found no appreciable direct effects on birds, following one pound per acre application of DDT to forest areas. Although insect populations were sharply but temporarily reduced, there appeared to be sufficient numbers of resistant or newly emergent forms to provide food for song birds. Nestlings in the treated areas did not show symptons of DDT poisoning. In semi-field tests young birds from the nests showed a normal survival when fed DDT killed spruce budworm larvae to the extent of 25 to 50 percent of their body weight daily. Losses were obtained through partial starvation. This agrees with experiments on other animals. DDT poisoning may be increased by partial starvation. In control work under certain circumstances it is conceivable that losses might occur in the same way.

It can be concluded, however, that birds are less susceptible than fish and that the use of one pound per acre dosage is not likely to have any noticeable effect on forest bird populations.

MAMMALS

Studies by the Fish and Wildlife Service and observations of sprayed areas has failed to determine losses of forest mammals that could be definitely attributed to DDT where 1 pound per acre was applied.

In Idaho over 400,000 acres of coniferous forest was treated with one pound of DDT per acre for control of the Douglas-fir tussock moth. Fairly detailed studies were made of the small mammals, birds and fish in the area. Some of the study areas were within large continuous blocks of treated forest. Harmful effects were negligible for birds, fish and mammals.

HONEY BEES

Honey bees are very susceptible to DDT and heavy loss will result if apiaries are sprayed.

SUMMARY

In the control of forest insect pests by aerial spraying with amounts of one pound or less of DDT per acre, the following statements apply insofar as present studies and knowledge indicates:

1. There is no danger to man or livestock. Injury could result from accidents or carelessness in handling the spray in loading operations, etc.

2. Fish are sensitive to DDT but excessive fish loss has not occurred that could be positively attributed to the spraying of such low dosage except the loss of young salmon on the Miramichi River in Canada and on Meadow Creek in Oregon. In both cases the loss will not result in permanent damage or complete loss of the salmon run as has occured on one reported deforested drainage in Canada.

3. Aquatic insects providing food for fish in ponds, lakes and streams are affected in varying degrees. The temporary effect on aquatic organisms can be drastic but no permanent injury to waters in spray areas has occurred, and fish populations do not seem to have been seriously affected by the loss of food organisms.

4. Crayfish are especially sensitive and losses can be expected from spraying operations of DDT.

5. Damage to birds and small mammals is not likely to occur with dosage at one pound per acre.

6. Honey bees are very susceptible and care should be taken to avoid apiaries. Ranchers keeping bees in spray areas should be notified well in advance of spraying.

7. The amounts of DDT reaching the ground or water surface is extremely variable. It can therefore be expected that effects on forest wildlife, fish and aquatic insects will also be extremely variable.

8. Careful handling of the spray with every effort being made to avoid, as far as possible, direct application to streams and lakes, will greatly minimize losses of aquatic life.

9. The control of many forest insects with DDT seems assured with dosages of sufficiently low concentration to cause no serious or permanent injury to beneficial insects and other animal life.

10. The chance for loss of desirable species of forest wildlife and insects, as well as trees, can be greatly minimized by affecting control programs before infestations cover large acreages of forest land.

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